An Investigation into the Impacts of Performing a Ballast Water Exchange at Sea on Typical PANAMAX Containerships

Appendix 1 & 2

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APPENDIX 1

Ship Data

The three ship's selected for this analysis included a 1970 TEU ship (28,000 dwt), a 2824 TEU ship (35,000 dwt), and a 3918 TEU ship (46,000 dwt). These ships are at Panamax beam and range in length from 713.5 to 860 ft (217.5 to 262 m).

1970 TEU Panamax Containership

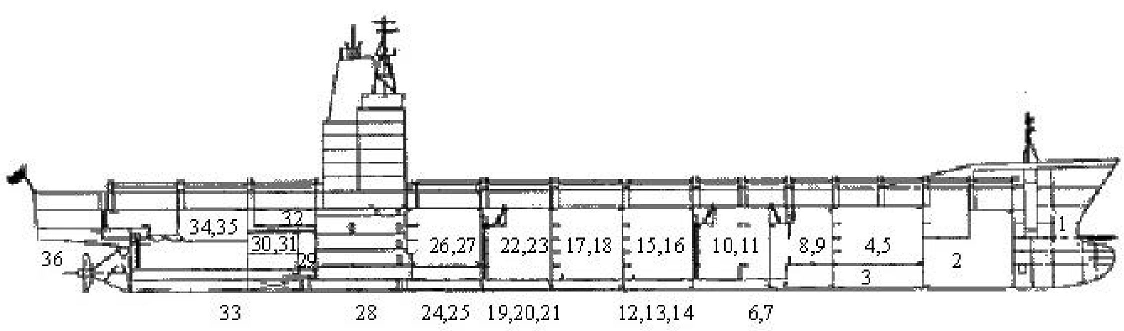
The 1970 TEU ship is the smallest of the three ships used in the analysis. A general arrangement is shown in Figure 1. Its principal particulars are as follows:

Loa:	713.5 ft	(217.5 m)	
Lbp:	673.1 ft	(205.2 m)	
B:	105.75 ft	(32.2 m)	
D:	66.5 ft	(20.3 m)	
T:	38.1 ft	(11.6 m)	Summer Draft
Displacement:	42,459 LT	(43,141 t)	
Capacity:	28,582 LT	(29,041 t)	
DWT:	28,000		

This ship was built in the early 1990's and serves in the Pacific container trade. Data for the cargo loadouts for this ship were obtained from computer printouts provided by HEC of actual voyages for all the legs of a trans-Pacific transit that the ship recently performed. Data from the leg of the voyage on which the ship carried the heaviest cargo was used as the Full Cargo Condition for this analysis. Data from the leg of the voyage on which the ship carried the lightest cargo was used as the Light Cargo Condition. From the data provided, the fuel and stores distribution for the ship approximating 98% capacity, 50% capacity, and 10% capacity were also estimated.

Table 1 shows the ballast tank arrangements for this ship and summarizes which of the tanks are filled in each of the operating conditions investigated. Table 2 summarizes the cargo distribution for the full cargo and light cargo loadouts. Table 3 summarizes the mission profile data for this ship obtained from computer printouts of actual voyages for all the legs of a trans-Pacific transit that the ship recently performed. Table 4 summarizes the initial GM margin available, the maximum Bending Moment (BM) and Shear Force (SF) experienced, the percent propeller immersion, and the ship's trim, prior to conducting a BWE for each of the six standard operating conditions analyzed in this report. The bending moment and shear force are listed as a percent of the maximum allowable bending moments and shear forces and the propeller immersion is stated as a percent of the propeller diameter.

Figure 4: General Arrangement 1970 TEU Containership



1 FOREPEAK	10 #3 AFT TK (P)	19 #5 DBT (P)	28 HFO SERV TR
2 #1 TK (C)	11 #3 AFT TK (S)	20 #5 DBT (S)	29 DO STRG
3 #2 DBT (C)	12 #4 DBT (P)	21 #5 DBT (C)	30 #6 TK (P)
4 #2 TK (P)	13 #4 DBT (C)	22 #5 FWD TK (P)	31 #6 TK (S)
5 #2 TK (S)	14 #4 DBT (C)	23 #5 FWD TK (S)	32 FWTK
6 #3 DBT (P)	15 #4 FWD TK (P)	24 #5 AFT TK (P)	33 #7 DBT (C)
7 #3 DBT (S)	16 #4 FWD TK (S)	25 #5 AFT TK (S)	34 #7 TK (P)
8 #3 FWD (P)	17 #4 AFT TK (P)	26 HEEL TK (P)	35 #7 TK (S)
9 #3 FWD (S)	18 #4 AFT TK (S)	27 HEEL TK (S)	36 AFT PEAK

Table 1 1970 TEU Ship - Ballast Distribution						
Ballast Tank (or Tank Pair)	**Light Cargo Load**			**Full Cargo Load**		
	Level of Consumables LT (mt)			Level of Consumables LT (mt)		
	10%	50%	98%	10%	50%	98%
Fore Peak Tank (Centerline)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
No 1 Tank (Centerline)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
No 2 Double Bottom Tank (Centerline)	568 (577)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
No 2 Tank (P/S)	748/748 (760/760)	748/748 (760/760)	748/748 (760/760)	748/748 (760/760)	561/561 (569/569)	561/561 (569/569)
No 3 Double Bottom Tank (P/S)	512/512 (520/520)	512/512 (520/520)	512/512 (520/520)	512/512 (520/520)	512/512 (520/520)	512/512 (520/520)
No 4 FWD Tank (P/S)	756/756 (768/768)	756/756 (768/768)	756/756 (768/768)	756/756 (768/768)	756/756 (768/768)	756/756 (768/768)
No 4 Double Bottom Tank (P/S)	377/377 (383/383)	377/377 (383/383)	377/377 (383/383)	377/377 (383/383)	377/377 (383/383)	377/377 (383/383)
No 4 AFT Tank (P/S)	718/718 (730/730)	718/718 (730/730)	718/718 (730/730)	718/718 (730/730)	718/718 (730/730)	72/72 (73/73)
No 5 Double Bottom Tank (P/S)	0/0 (0/0)	0/0 (0/0)	0/0 (0/0)	0/0 (0/0)	0/0 (0/0)	0/0 (0/0)
No 5 FWD Tank (P/S)	0/0 (0/0)	0/0 (0/0)	0/0 (0/0)	0/0 (0/0)	0/0 (0/0)	0/0 (0/0)
No 5 AFT Tank (P/S)	0/0 (0/0)	0/0 (0/0)	0/0 (0/0)	120/120 (122/122)	0/0 (0/0)	0/0 (0/0)
Heel Tanks (P/S)	0/0 (0/0)	0/0 (0/0)	0/0 (0/0)	0/0 (0/0)	216/130 (219/132)	87/0 (88/0)
No 6 Tank (P/S)	0/0 (0/0)	0/0 (0/0)	0/0 (0/0)	0/0 (0/0)	0/0 (0/0)	0/0 (0/0)
No 7 Double Bottom Tank (Centerline)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
No 7 Tank (P/S)	0/0 (0/0)	0/0 (0/0)	0/0 (0/0)	0/0 (0/0)	0/0 (0/0)	0/0 (0/0)
Totals	6792 (6901)	6224 (6324)	6224 (6324)	6465 (6569)	6196 (6600)	4644 (4719)

Table 2 1970 TEU Ship - Cargo Distribution				
Container Bay	**Light Cargo Load**		**Full Cargo Load**	
	LT	mt	LT	mt
01	0	0	469	477
02	0	0	580	589
03	298	303	604	614
04	19	19	1,187	1,206
05	443	450	1,071	1,088
06	0	0	0	0
07	187	190	1,828	1,857
08	348	354	1,730	1,758
09	0	0	250	254
10	520	528	1,614	1,640
11	176	179	1,684	1,711
12	1,128	1,146	1,953	1,984
13	82	83	1,952	1,983
14	227	231	1,369	1,391
15	233	237	1,277	1,298
16	61	62	630	640
17	0	0	0	0
Total	3,722	3,782	18,198	18,490

Table 3 1970 TEU Ship - Typical Voyage Data						
Voyage Leg	**Length of Voyage (hrs)**	**Cargo LT (mt)**	**Ballast LT (mt)**		**Fuel Barrels (%Capacity)**	
			@ Departure	@ Arrival	@ Departure	@ Arrival
Honolulu to Guam	157	12,733 (12,937)	4,387 (4,457)	4,637 (4,711)	13,060 68%	6,924 36%
Oakland to Honolulu	95	18,198 (18,490)	3,775 (3,836)	4,175 (4,242)	15,526 81%	12,650 66%
Terminal Island to Oakland	19	3,722 (3,782)	1,934 (1,965)	1,934 (1,965)	16,271 85%	15,912 83%
Yokohama to Terminal Island	208	11,059 (11,237)	893 (907)	1043 (1,060)	14,889 77%	8,971 47%
Pusan to Yokohama	47	6,078 (6,176)	2,621 (2,663)	2,621 (2,663)	15,833 82%	14,907 77%
Naha to Pusan	27	6,412 (6,515)	4,562 (4,635)	4,562 (4,635)	6,945 36%	6,292 33%
Honolulu to Guam	164	9,990 (10,150)	2,592 (2,634)	2,792 (2,837)	12,233 64%	7,991 42%

Table 4 Initial Stability, Strength, and Trim Data for the 1970 TEU Ship Prior to Conducting a BWE									
Operating Condition	**Available GM Margin**		**Max BM**	**Max SF**	**Prop Immersion**	**Trim**			**Notes**
	Ft	m	(% Allow)		(%)	Ft	m	%L	
Full Load 98% Consumables	3.38	1.03	95	59	142	-0.13	-0.04	-0.02	1
Full Load 50% Consumables	3.29	1.00	90	59	142	-0.25	-0.08	-0.04	1
Full Load 10% Consumables	2.67	0.81	90	75	141	0.76	0.23	0.11	
Light Load 98% Consumables	15.28	4.66	65	39	106	-0.93	-0.28	-0.14	1
Light Load 50% Consumables	14.86	4.56	68	44	103	-0.55	-0.17	-0.08	1
Light Load 10% Consumables	15.17	4.62	68	63	101	-0.45	-0.14	-0.07	1

Notes: 1) In these operating conditions, the ship initially has a small amount of trim by the bow. Based on the typical voyage data provided for this ship, this amount of bow trim is not expected to adversely affect normal ship operations.

As can be seen from Table 1, for this ship, several ballast tanks are maintained full in all the operating conditions investigated. It is possible that these tanks are normally always kept full for stability or strength reasons. Therefore, it may not be necessary to perform a BWE evolution on these tanks on every leg of a voyage. Once these tanks have their coastal sea water exchanged with open ocean sea water, it would not be necessary to perform another BWE evolution on these tanks during later legs of a voyage, unless they are at some point deballasted and reballasted in port.

No data on the ballast pump capacity was available for this ship. A review of the Classification Society requirements gives a minimum bilge pump capacity (which can serve double duty as a bilge and ballast pump) for this size ship of 982 gph (223 m^3/hr).

2824 TEU Panamax Containership

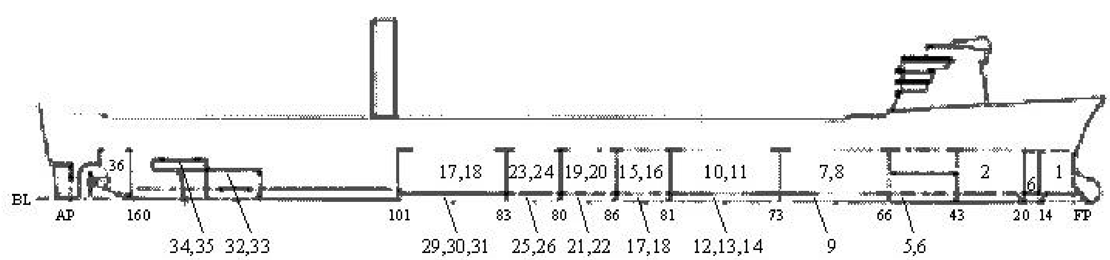
The 2824 TEU ship is the midrange of the three ships used in the analysis. A general arrangement is shown in Figure 2. Its principal particulars are as follows:

Loa:	860.17 ft	(262.2 m)	
Lbp:	810.0 ft	(246.9 m)	
B:	105.75 ft	(32.2 m)	
D:	66.0 ft	(20.3 m)	
T:	38.1 ft	(11.6 m)	Summer Draft
Displacement:	54,977 LT	(43,141 t)	
Capacity:	35,148 LT	(29,041 t)	
DWT:	35,000		

This ship was built in the early 1980's and is operated in the Pacific container trade. Data for the cargo loadouts for this ship were obtained from computer printouts provided by HEC of actual voyages for all the legs of a trans-Pacific transit that the ship recently performed. Data from the leg of the voyage on which the ship carried the heaviest cargo was used as the Full Cargo Condition for this analysis. Data from the leg of the voyage on which the ship carried the lightest cargo was used as the Light Cargo Condition. From the data provided, the fuel and stores distribution for the ship approximating 98% capacity, 50% capacity, and 10% capacity were also estimated.

Table 5 shows the ballast tank arrangements for this ship and summarizes which of the tanks are filled in each of the operating conditions investigated. Table 6 summarizes the cargo distribution for the full cargo and light cargo loadouts. Table 7 summarizes the mission profile data for this ship obtained from computer printouts of actual voyages for all the legs of a trans-Pacific transit that the ship recently performed. Table 8 summarizes the initial GM margin available, the maximum Bending Moment (BM) and Shear Force (SF) experienced, the percent propeller immersion, and the ship's trim, prior to conducting a BWE for each of the six standard operating conditions analysed in this report. The bending moment and shear force are listed as a percent of the maximum allowable bending moments and shear forces and the propeller immersion is stated as a percent of the propeller diameter.

Figure 5: General Arrangement 2824 TEU Panamax Containership



1 FPWB (C)
2 #1 WB (C)
3 #2 UPP FO (P)
4 #2 UPP FO (S)
5 #2 DEEP WB (P)
6 #2 DEEP WB (S)
7 #1 WINGTANK FO (P)
8 #1 WINGTANK FO (S)
9 #1 DBT WB (C)
10 #2 WINGTANK FO (P)
11 #2 WINGTANK FO (S)
12 #2 DBT WB (C)
13 #2 DBT WB (P)
14 #2 DBT WB (S)
15 #3A WINGTANK FO (P)
16 #3A WINGTANK FO (S)
17 #3A DBT WB (P)
18 #3A DBT WB (S)
19 #3B WINGTANK FO (P)
20 #3B WINGTANK FO (S)
21 #3B DBT WB (P)
22 #3B DBT WB (S)
23 #3C WINGTANK FO (P)
24 #3C WINGTANK FO (S)
25 #3C DBT WB (P)
26 #3C DBT WB (S)
27 #4 WINGTANK WB (P)
28 #4 WINGTANKWB (S)
29 #4 DBT WB (C)
30 #4 DBT WB (P)
31 #4 DBT WB (S)
32 #6A DEEP WB (P)
33 #6A DEEP WB (S)
34 #6B DEEP WB (P)
35 #6B DEEP WB (S)
36 AP TANK WB (C)

Table 5 2824 TEU Ship - Ballast Distribution						
Ballast Tank (or Tank Pair)	**Light Cargo Load**			**Full Cargo Load**		
	Level of Consumables LT (mt)			Level of Consumables LT (mt)		
	10%	50%	98%	10%	50%	98%
Fore Peak Tank (Centerline)	429 (436)	429 (436)	429 (436)	429 (436)	429 (436)	215 (218)
No 1 Deep Tank (Centerline)	1272 (1292)	1272 (1292)	0 (0)	636 (646)	636 (646)	0 (0)
No 2 Deep Lower Tanks (P/S)	482/482 (490/490)	0/0 (0/0)	0/0 (0/0)	0/0 (0/0)	0/0 (0/0)	0/0 (0/0)
No 1 Double Bottom Tank (Centerline)	473 (481)	473 (481)	473 (481)	473 (481)	473 (481)	0 (0)
No 2 Double Bottom Tank (P/S)	169/169 (172/172)	169/169 (172/172)	169/169 (172/172)	169/169 (172/172)	169/169 (172/172)	169/169 (172/172)
No 2 Double Bottom Tank (Centerline)	535 (544)	535 (544)	535 (544)	535 (544)	535 (544)	535 (544)
No 3A Double Bottom Tank (P/S)	160/160 (163/163)	160/160 (163/163)	160/160 (163/163)	160/160 (163/163)	160/160 (163/163)	160/160 (163/163)
No 3B Double Bottom Tank (P/S)	196/196 (199/199)	196/196 (199/199)	196/196 (199/199)	196/196 (199/199)	196/196 (199/199)	196/196 (199/199)
No 3C Double Bottom Tank (P/S)	205/205 (208/208)	205/205 (208/208)	205/205 (208/208)	205/205 (208/208)	205/205 (208/208)	205/205 (208/208)
No 4 Double Bottom Tank (P/S)	296/296 (301/301)	296/296 (301/301)	296/296 (301/301)	296/296 (301/301)	0/296 (0/301)	0/296 (0/301)
No 4 Double Bottom Tank (Centerline)	269 (273)	0 (0)	0 (0)	537 (546)	537 (546)	537 (546)
No 4 Wing Tank (P/S)	644/805 (654/818)	0/161 (0/164)	0/161 (0/164)	0/0 (0/0)	0/0 (0/0)	0/0 (0/0)
No 6A Deep Tank (P/S)	0/0 (0/0)	0/0 (0/0)	0/0 (0/0)	302/0 (307/0)	0/0 (0/0)	0/0 (0/0)
No 6B Deep Tank (P/S)	0/0 (0/0)	0/0 (0/0)	0/0 (0/0)	202/0 (205/0)	0/0 (0/0)	0/0 (0/0)
Aft Peak Tank (Centerline)	0/0 (0/0)	0/0 (0/0)	0/0 (0/0)	0/0 (0/0)	0/0 (0/0)	0/0 (0/0)
Totals	7,443 (7,563)	4,922 (5,003)	3,652 (3,711)	5,167 (5,250)	4,366 (4,436)	3,044 (3,093)

Table 6 2824 TEU Ship - Cargo Distribution				
Container Bay	**Light Cargo Load**		**Full Cargo Load**	
	LT	mt	LT	Mt
01	0	0	469	477
02	0	0	580	589
03	298	303	604	614
04	19	19	1,187	1,206
05	443	450	1,071	1,071
06	0	0	0	0
07	187	190	1,828	1,857
08	348	354	1,730	1,758
09	0	0	250	254
10	520	528	1,614	1,640
11	176	179	1,684	1,711
12	1,128	1,146	1,953	1,984
13	82	83	1,952	1,983
14	227	231	1,369	1,391
15	233	237	1,277	1,298
16	61	62	630	640
17	0	0	0	0
Total	3,722	3,782	18,198	18,674

Table 7 2824 TEU Ship - Typical Voyage Data						
Voyage Leg	**Length of Voyage (hrs)**	**Cargo LT (mt)**	**Ballast LT (mt)**		**Fuel LT (mt)[%Capacity]**	
			@ Departure	@ Arrival	@ Departure	@ Arrival
San Pedro to Oakland	11	4,989 (5,069)	2,322 (2,359)	2,322 (2,359)	2,805 (2,850) [35%]	2,732 (2,776) [45%]
Yokohama to San Pedro	205	17,576 (17,858)	2,526 (2,567)	2,526 (2,567)	3,939 (4,002) [65%]	2,657 (2,700) [44%]
Nagoya to Yokohama	11	15,092 (15,334)	2,702 (2,745)	2,702 (2,745)	3,989 (4,053) [66%]	3,939 (4,002) [65%]
Hakata to Nagoya	34	9,680 (9,835)	2,703 (2,746)	2,703 (2,746)	4,149 (4,216) [69%]	3,989 (4,053) [66%]
Pusan to Hakata	6	9,877 (10,036)	3,659 (3,718)	3,659 (3,718)	4,251 (4,319) [70%]	4,101 (4,167) [68%]
Guam to Pusan	100.5	11,100 (11,278)	3,267 (3,319)	3,267 (3,319)	1,374 (1,396) [23%]	1022 (1,038) [17%]
Honolulu to Guam	114	14,584 (14,818)	4,070 (4,135)	4,070 (4,135)	2,349 (2,387) [39%]	1,603 (1,629) [27%]
Oakland to Honolulu	94	19,853 (20,172)	4,009 (4,073)	4,009 (4,073)	2,760 (2,805) [46%]	2,186 (2,221) [36%]
San Pedro to Oakland	11	5,514 (5,603)	4,430 (4,501)	4,430 (4,501)	2,764 (2808) [46%]	2,678 (2,721) [44%]

Table 8 Initial Stability, Strength, and Trim Data for the 2824 TEU Ship Prior to Conducting a BWE									
Operating Condition	**Available GM Margin**		**Max BM**	**Max SF**	**Prop Immersion**	**Trim**			**Notes**
	Ft	m	(% Allow)		(%)	Ft	m	%L	
Full Load 98% Consumables	0.73	0.22	61	44	144	-0.63	-0.19	-0.08	1
Full Load 50% Consumables	0.64	0.20	66	48	143	0.85	0.26	0.10	
Full Load 10% Consumables	0.50	0.15	73	56	148	5.60	1.71	0.69	
Light Load 98% Consumables	8.88	2.71	83	55	111	0.11	0.03	0.01	
Light Load 50% Consumables	8.91	2.72	90	58	106	0.23	0.07	0.03	
Light Load 10% Consumables	9.34	2.85	98	78	105	-0.03	-0.01	-0.00	1

Notes: 1) In these operating conditions, the ship initially has a small amount of trim by the bow. Based on the typical voyage data provided for this ship, this amount of bow trim is not expected to adversely affect normal ship operations.

As can be seen from Table 5, for this ship, several ballast tanks are maintained full in all the operating conditions investigated. It is possible that these tanks are normally always kept full, for stability or strength reasons. If this were the case then it would not be necessary to perform a BWE evolution on these tanks on every leg of a voyage. Once these tanks have their coastal seawater exchanged with open ocean seawater, it would not be necessary to perform another BWE evolution on these tanks during later legs of a voyage, unless they are at some point deballasted and reballasted in port.

No data on the ballast pump capacity was available for this ship. A review of the Classification Society requirements give a minimum bilge pump capacity (which can serve double duty as a bilge and ballast pump) for this size ship of 1152 gph (262 m^3/hr).

3918 TEU Panamax Containership

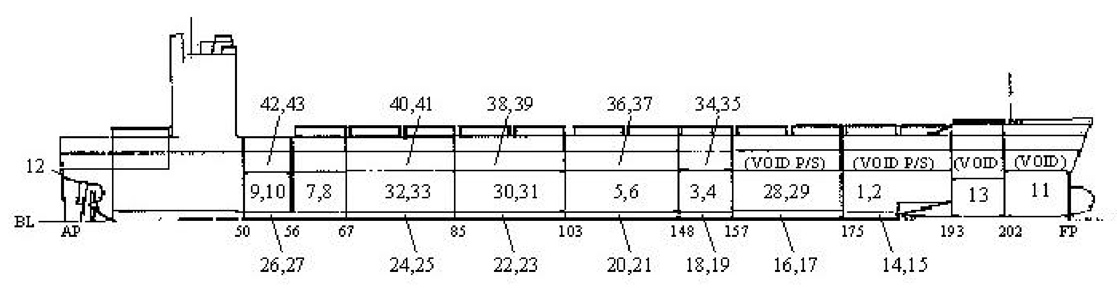
The 3918 TEU ship is the largest of the three ships used in the analysis. A general arrangement is shown in Figure 3. Its principal particulars are as follows:

Loa:	856.4 ft	(261.0 m)	
Lbp:	814.5 ft	(248.3 m)	
B:	105.75 ft	(32.2 m)	
D:	70.5 ft	(21.5 m)	
T:	38.3 ft	(11.7 m)	Summer Draft
Displacement:	67,172 LT	(68,251 t)	
Capacity:	46,245 LT	(46,988 t)	
DWT:	46,000		

This ship was originally built for the around the world container trade in the mid 1980's. Since its construction it has been modified in order to increase its overall speed and decrease its overall container capacity. Data for the cargo loadouts for this ship were obtained from the ship's trim and stability booklet, which was provided by HEC. For this ship in lieu of performing the BWE analysis for the ship in a full load and ballast condition with 50% consumables onboard, calculations were performed for a mid-range cargo loadout, identified as the Design Cargo Configuration in the trim and stability booklet. Calculations were performed for this design cargo loadout at both a 98% level of consumables and at a 10% level of consumables. By performing the calculations at an intermediate cargo loadout configuration it was possible to obtain a better picture of the impact of cargo distribution on the ability of a ship to perform a BWE at sea.

Table 9 shows the ballast tank arrangements on for this ship and summarizes which of the tanks are filled in each of the operating conditions investigated. Table 10 summarizes the cargo distribution for the full cargo, design cargo, and ballast loadouts as obtained from the ship's trim and stability booklet. Table 11 summarizes the initial GM margin available, the maximum Bending Moment (BM) and Shear Force (SF) experienced, the percent propeller immersion, and the ship's trim, prior to conducting a BWE for each of the six standard operating conditions analyzed in this report. The bending moment and shear force are listed as a percent of the maximum allowable bending moments and shear forces and the propeller immersion is stated as a percent of the propeller diameter.

Figure 6: General Arrangement 3918 TEU Panamax Containership



1 #1 HFO (P)	9 #9B DO (P)	17 #2 DBT (S)	25 #8 DBT (S)	33 #8 WB (S)	41 #8 UPP (S)
2 #1 HFO (S)	10 #9B DO (S)	18 #3 DBT (P)	26 #9 DBT (P)	34 #3 UPP (P)	42 #9B V/O (P)
3 #3 HFO (P)	11 FOREPEAK	19 #3 DBT (S)	27 #9 DBT (S)	35 #3 UPP (S)	43 #9B V/O (S)
4 #3 HFO (S)	12 AFTPEAK	20 #4 DBT (P)	28 #2 WB (P)	36 #4 UPP (P)	
5 #4 HFO (P)	13 #1 DEEP (C)	21 #4 DBT (S)	29 #2 WB (S)	37 #4 UPP (S)	
6 #4 HFO (S)	14 #1 DBT (P)	22 #7 DBT (P)	30 #7 WB (P)	38 #7 UPP (P)	
7 #9AIFO (P)	15 #1 DBT (S)	23 #7 DBT (S)	31 #7 WB (P)	39 #7 UPP (S)	
8 #9AIFO (S)	16 #2 DBT (P)	24 #8 DBT (P)	32 #8 WB (P)	40 #8 UPP (P)	

Table 9 3918 TEU Ship - Ballast Distribution						
Ballast Tank (or Tank Pair)	**Ballast Condition**		**Design Condition**		**Full Cargo Load**	
	Level of Consumables		Level of Consumables		Level of Consumables	
	10%	98%	10%	98%	10%	98%
Fore Peak Tank (Centerline)	0/0 (0/0)	0/0 (0/0)	0/0 (0/0)	0/0 (0/0)	0/0 (0/0)	0/0 (0/0)
No 1 Deep Tank (Centerline)	1224 (1243)	1224 (1243)	1224 (1243)	1224 (1243)	1224 (1243)	1224 (1243)
No 1 Double Bottom Tank (P/S)	458/458 (465/465)	458/458 (465/465)	458/458 (465/465)	458/458 (465/465)	458/458 (465/465)	458/458 (465/465)
No 2 Double Bottom Tank (P/S)	396/396 (402/402)	396/396 (402/402)	396/396 (402/402)	396/396 (402/402)	396/396 (402/402)	396/396 (402/402)
No 3 Double Bottom Tank (P/S)	282/282 (287/287)	282/282 (287/287)	282/282 (287/287)	282/282 (287/287)	282/282 (287/287)	282/282 (287/287)
No 4 Double Bottom Tank (P/S)	620/620 (630/630)	620/620 (630/630)	620/620 (630/630)	620/620 (630/630)	620/620 (630/630)	620/620 (630/630)
No 7 Double Bottom Tank (P/S)	608/608 (618/618)	608/608 (618/618)	608/608 (618/618)	608/608 (618/618)	608/608 (618/618)	608/608 (618/618)
No 8 Double Bottom Tank (P/S)	557/557 (566/566)	557/557 (566/566)	557/557 (566/566)	557/557 (566/566)	557/557 (566/566)	557/557 (566/566)
No 9 Double Bottom Tank (P/S)	336/336 (341/341)	336/336 (341/341)	336/336 (341/341)	0/0 (0/0)	336/336 (341/341)	336/336 (341/341)
No 2 Wing Ballast Tank (P/S)	840/840 (853/853)	840/840 (853/853)	840/840 (853/853)	840/840 (853/853)	840/840 (853/853)	840/840 (853/853)
No 7 Wing Ballast Tank (P/S)	739/739 (751/751)	739/739 (751/751)	739/739 (751/751)	0/0 (0/0)	739/739 (751/751)	487/238 (495/242)
No 8 Wing Ballast Tank (P/S)	712/712 (723/723)	712/712 (723/723)	0/0 (0/0)	0/0 (0/0)	712/712 (723/723)	0/0 (0/0)
No 3 Upper Tank (P/S)	194/194 (197/197)	194/194 (197/197)	0/0 (0/0)	194/194 (197/197)	0/0 (0/0)	0/0 (0/0)
No 4 Upper Tank (P/S)	396/396 (402/402)	396/396 (402/402)	396/332 (402/337)	290/40 (295/41)	0/0 (0/0)	0/0 (0/0)
No 7 Upper Tank (P/S)	389/389 (395/395)	389/389 (395/395)	0/0 (0/0)	0/0 (0/0)	0/0 (0/0)	0/0 (0/0)
No 8 Upper Tank (P/S)	389/389 (395/395)	389/389 (395/395)	0/0 (0/0)	0/0 (0/0)	0/0 (0/0)	0/0 (0/0)
Aft Peak Tank (Centerline)	0/0 (0/0)	0/0 (0/0)	0/0 (0/0)	0/0 (0/0)	0/0 (0/0)	0/0 (0/0)
Totals	15,055 (15,297)	15,055 (15,297)	12,424 (12,623)	9,464 (9,616)	12,320 (12,518)	10,143 (10,306)

Table 10 3918 TEU Ship - Cargo Distribution						
Container Bay	**Ballast Condition**		**Design Cargo Load**		**Full Cargo Load**	
	LT	mt	LT	mt	LT	mt
2	0	0	650	660	830	843
6	0	0	933	948	1,244	1,264
10	0	0	1,192	1,211	1,732	1,760
14	0	0	1,335	1,356	2,394	2,432
18	0	0	1,382	1,404	2,533	2,574
22	0	0	1,405	1,428	2,606	2,648
26	0	0	1,405	1,428	2,163	2,198
30	0	0	1,405	1,428	2,163	2,198
34	0	0	1,405	1,428	2,163	2,198
38	0	0	1,405	1,428	2,163	2,198
42	0	0	1,405	1,428	2,163	2,198
46	0	0	1,405	1,428	2,163	2,198
50	0	0	1,358	1,380	2,057	2,090
54	0	0	1,039	1,056	1,453	1,476
58	0	0	697	708	864	878
62	0	0	437	444	561	570
Total	0	0	18,861	19,164	29,253	29,723

Table 11 Initial Stability, Strength, and Trim Data for 3918 TEU Ship Prior to Conducting a BWE									
Operating Condition	**Available GM Margin**		**Max BM**	**Max SF**	**Prop Immersion**	**Trim**			**Notes**
	Ft	m	(% Allow)		(%)	Ft	m	%L	
Full Load 98% Consumables	2.07	0.63	82	71	161	0.69	0.21	0.08	
Full Load 10% Consumables	0.95	0.29	58	38	159	3.67	1.12	0.45	
Design Load 98% Consumables	1.38	0.42	96	94	141	2.26	0.69	0.28	
Design Load 10% Consumables	1.21	0.37	80	69	132	1.74	0.53	0.21	
Ballast Cond. 98% Consumables	12.83	3.91	76	91	127	10.04	3.06	1.23	
Ballast Cond. 10% Consumables	12.96	3.95	61	57	112	9.84	3.00	1.21	

As can be seen from Table 9, for this ship, several ballast tanks are maintained full in all the operating conditions investigated. It is possible that these tanks are normally always kept full, for stability or strength reasons. If this were the case then it would not be necessary to perform a BWE evolution on these tanks on every leg of a voyage. Once these tanks have their coastal sea water exchanged with open ocean seawater, it would not be necessary to perform another BWE evolution on these tanks during later legs of a voyage, unless they are at some point deballasted and reballasted in port.

No data on the ballast pump capacity was available for this ship. A review of the Classification Society requirements give a minimum bilge pump capacity (which can serve double duty as a bilge and ballast pump) for this size ship of 1185 gph (269 m^3/hr).

APPENDIX 2

Analysis

1970 TEU Panamax Containership

The results of the BWE analysis for the 1970 TEU ship are shown in Tables 12 through 18. These tables show the impact on the ship's available GM, maximum bending moment, maximum shear stress, propeller immersion, and trim experienced by the ship as each ballast tank or tank pair is cycled during the BWE evolution for each loading condition investigated. Available GM is shown as the Margin in GM that the ship has above its minimum requirements at the ship's current draft and trim. Conditions where this margin is less than 0.5ft (0.15m) have been shaded for easy identification. The maximum bending moment and shear forces experienced when cycling each tank or tank pair is shown as a percent of the maximum allowable bending moments and shear forces for the vessel. Conditions where the maximum bending moment and shear forces exceed 95% of the allowable bending moment or shear forces have been shaded for easy identification. Propeller immersion is measured as the draft at the propeller as a percent of the propeller diameter. Conditions where the propeller immersion is less than 105% of the propeller diameter have been shaded for easy identification. Table 18 shows the estimated time required to complete a BWE evolution for each of the six loading conditions investigated. Two different time estimates are shown in Table 18. The first is for a complete BWE in which all the ballast tanks, which were filled in the given loading condition, were cycled. The second is for a limited BWE that excludes those tanks maintained full for all levels of consumables for the operating condition investigated.

Table 12 BWE Analysis Results for the 1970 TEU Ship - Full Load Cargo 10% Consumables

Tank or Tank Pair	% Full	GM Margin		Max BM	Max SF	Prop Imm.	Trim			Notes
		Ft	m	(% Allow)		(%)	Ft	m	[%L]	
No 2 Tank (P/S)	50%	2.88	0.87	85	62	144	3.74	1.14	0.55	
	0%	2.89	0.88	79	48	148	6.87	2.09	1.02	
No 3 DBT (P/S)	50%	2.23	0.68	89	79	142	2.19	0.67	0.33	
	0%	1.91	0.58	88	84	143	3.67	1.12	0.55	
No 4 FWD Tank (P/S)	50%	2.53	0.77	92	80	141	1.97	0.60	0.29	
	0%	1.97	0.60	94	84	141	3.23	0.98	0.48	
No 4 DBT (P/S)	50%	2.25	0.69	92	77	141	1.24	0.38	0.18	
	0%	1.89	0.58	93	79	141	1.74	0.53	0.26	
No 4 AFT Tank (P/S)	50%	2.50	0.76	95	78	140	1.36	0.41	0.20	
	0%	1.80	0.59	99	82	139	1.97	0.60	0.29	
No 5 AFT Tank (P/S)	0%	2.42	0.74	92	76	140	0.60	0.18	0.09	

Table 13 BWE Analysis Results for the 1970 TEU Ship - Full Load Cargo 50% Consumables										
Tank or Tank Pair	**% Full**	**GM Margin**		**Max BM**	**Max SF**	**Prop Imm.**	**Trim**			**Notes**
		Ft	m	(% Allow)		(%)	Ft	m	[%L]	
No 2 Tank (P/S)	0%	3.29	1.00	81	39	147	4.10	1.25	0.61	
No 3 DBT (P/S)	50%	2.87	0.91	89	63	143	1.13	0.34	0.17	
	0%	2.54	0.77	87	68	144	2.55	0.78	0.38	
No 4 FWD Tank (P/S)	50%	3.16	0.96	92	64	142	0.91	0.28	0.14	
	0%	2.61	0.80	94	68	142	2.11	0.64	0.31	
No 4 DBT (P/S)	50%	2.89	0.88	91	61	142	0.22	0.07	0.03	
	0%	2.54	0.77	93	63	142	0.69	0.21	0.10	
No 4 AFT Tank (P/S)	50%	3.13	0.95	94	62	141	0.32	0.10	0.05	
	0%	2.46	0.75	98	66	140	0.91	0.28	0.14	
Heel Tanks (P/S)	0%	3.04	0.93	93	60	141	-0.49	-0.15	-0.07	1

Notes: 1) In this operating condition, the ship initially has a –0.25 ft (-0.08 m) trim by the bow. When cycling this tank the ship will take on an additional small amount of bow trim. The magnitude of this trim by the bow is not expected to adversely affect normal ship operations.

Table 14 BWE Analysis Results for the 1970 TEU Ship - Full Load Cargo 98% Consumables										
Tank or Tank Pair	**% Full**	**GM Margin**		**Max BM**	**Max SF**	**Prop Imm.**	**Trim**			**Notes**
		Ft	m	(% Allow)		(%)	Ft	m	[%L]	
No 2 Tank (P/S)	0%	3.38	1.03	87	39	147	4.22	1.29	0.63	
No 3 DBT (P/S)	50%	2.96	0.90	94	64	143	1.25	0.38	0.19	
	0%	2.64	0.80	93	68	144	2.67	0.81	0.40	
No 4 FWD Tank (P/S)	50%	3.25	0.99	97	64	142	1.04	0.32	0.15	
	0%	2.71	0.83	99	68	143	2.24	0.68	0.33	
No 4 DBT (P/S)	50%	2.98	0.91	97	61	142	0.34	0.10	0.05	
	0%	2.63	0.80	98	64	142	0.82	0.25	0.12	
No 4 AFT Tank (P/S)	0%	3.25	0.99	96	60	142	-0.02	-0.01	0.00	1
Heel Tanks (P/S)	0%	3.31	1.01	96	59	142	-0.19	-0.06	-0.03	1

Notes: 1) In this operating condition, the ship initially has a –0.13 ft (-0.04 m) trim by the bow. When cycling this tank the ship will take on an additional small amount of bow trim. The magnitude of this trim by the bow is not expected to adversely affect normal ship operations.

Table 15 BWE Analysis Results for the 1970 TEU Ship - Light Load Cargo 10% Consumables										
Tank or Tank Pair	**% Full**	**GM Margin**		**Max BM**	**Max SF**	**Prop Imm.**	**Trim**			**Notes**
		Ft	m	(% Allow)		(%)	Ft	m	[%L]	
No 2 DBT (Centerline)	50%	15.01	4.58	66	58	103	1.05	0.32	0.16	
	0%	15.03	4.58	65	53	105	2.57	0.78	0.38	
No 2 Tank (P/S)	50%	15.97	4.87	64	50	106	3.55	1.08	0.53	
	0%	16.44	5.01	60	37	112	7.68	2.34	1.14	
No 3 DBT (P/S)	50%	14.82	4.52	67	67	103	1.36	0.41	0.20	
	0%	14.62	4.46	66	71	105	3.22	0.98	0.48	
No 4 FWD Tank (P/S)	50%	15.46	4.71	70	67	101	0.82	0.25	0.12	
	0%	15.07	4.59	73	71	101	2.11	0.64	0.31	
No 4 DBT (P/S)	50%	14.77	4.50	69	65	100	0.01	0.00	0.00	
	0%	14.45	4.40	71	67	100	0.47	0.14	0.07	
No 4 AFT Tank (P/S)	50%	15.55	4.74	71	67	101	0.86	0.26	0.13	1
	0%	14.95	4.56	77	70	100	1.23	0.37	0.18	1

Notes: 1) Analysis indicates that as long as HFO Tank 5 (Centerline) is the last tank from which fuel is drawn then the propeller tip will not emerge from the water when this tank is cycled.

Table 16 BWE Analysis Results for the 1970 TEU Ship - Light Load Cargo 50% Consumables										
Tank or Tank Pair	**% Full**	**GM Margin**		**Max BM**	**Max SF**	**Prop Imm.**	**Trim**			**Notes**
		Ft	m	(% Allow)		(%)	Ft	m	[%L]	
No 2 Tank (P/S)	50%	15.62	4.76	64	31	108	3.39	1.03	0.50	
	0%	16.05	4.89	60	20	114	7.45	2.27	1.11	
No 3 DBT (P/S)	50%	14.51	4.42	67	48	105	1.24	0.38	0.18	
	0%	14.31	4.36	67	52	107	3.07	0.94	0.46	
No 4 FWD Tank (P/S)	50%	15.12	4.61	70	48	103	0.71	0.22	0.11	
	0%	14.73	4.49	73	52	103	2.00	0.61	0.30	
No 4 DBT (P/S)	50%	14.46	4.41	69	46	103	-0.09	-0.03	-0.01	1
	0%	14.14	4.31	71	47	103	0.38	0.12	0.06	
No 4 AFT Tank (P/S)	50%	15.05	4.59	72	47	102	-0.17	-0.05	-0.02	1
	0%	14.46	4.41	77	49	100	0.19	0.06	0.03	

Notes: 1) In this operating condition, the ship initially has a –0.55 ft (-0.17 m) trim by the bow. The amount of trim by the bow experienced by the ship when cycling this tank is less than this initial amount of bow trim and thus should pose no operational difficulties.

Table 17 BWE Analysis Results for the 1970 TEU Ship - Light Load Cargo 98% Consumables										
Tank or Tank Pair	**% Full**	**GM Margin**		**Max BM**	**Max SF**	**Prop Imm.**	**Trim**			**Notes**
		Ft	m	(% Allow)		(%)	Ft	m	[%L]	
No 2 Tank (P/S)	50%	16.03	4.89	61	26	111	2.90	0.88	0.43	
	0%	16.49	5.03	57	19	117	6.85	2.09	1.02	
No 3 DBT (P/S)	50%	14.96	4.56	65	43	108	0.82	0.25	0.12	
	0%	14.78	4.50	64	47	110	2.61	0.80	0.39	
No 4 FWD Tank (P/S)	50%	15.53	4.73	67	43	107	0.32	0.10	0.05	
	0%	15.17	4.62	70	47	107	1.60	0.49	0.24	
No 4 DBT (P/S)	50%	14.91	4.54	67	41	106	-0.47	-0.14	-0.07	1
	0%	14.60	4.45	68	43	106	0.00	0.00	0.00	
No 4 AFT Tank (P/S)	50%	15.47	4.72	69	42	105	-0.54	-0.16	-0.01	1
	0%	14.91	4.54	74	44	104	-0.15	-0.05	-0.02	1

Notes: 1) In this operating condition, the ship initially has a –0.93 ft (-0.28 m) trim by the bow. The amount of trim by the bow experienced by the ship when cycling this tank is less than this initial amount of bow trim and thus should pose no operational difficulties.

Table 18 Estimated Time Requirements for BWE for the 1970 TEU Ship		
Operating Condition	**Time (hrs)**	
	Complete BWE	Limited BWE
Full Load 10% Consumables	28.7	14.1
Full Load 50% Consumables	27.5	12.9
Full Load 98% Consumables	20.6	6.0
Light Load 10% Consumables	30.2	2.5
Light Load 50% Consumables	27.7	0.0
Light Load 98% Consumables	27.7	0.0

2824 TEU Ship

The results of the BWE analysis for the 2824 TEU ship are shown in Tables 19 through 25. These tables show the impact on the ship's available GM, maximum bending moment, maximum shear stress, propeller immersion, and trim experienced by the ship as each ballast tank or tank pair is cycled during the BWE evolution for each loading condition investigated. Available GM is shown as the Margin in GM that the ship has above its minimum requirements at the ship's current draft and trim. Conditions where this margin is less than 0.5ft (0.15m) have been shaded for easy identification. The maximum bending moment and shear forces experienced when cycling each tank or tank pair is shown as a percent of the maximum allowable bending moments and shear forces for the vessel. Conditions where the maximum bending moment and shear forces exceed 95% of the allowable bending moment or shear forces have been shaded for easy identification. Propeller immersion is measured as the draft at the propeller as a percent of the propeller diameter. Conditions where the propeller immersion is less than 105% of the propeller diameter have been shaded for easy identification. Table 25 shows the estimated time required to complete a BWE evolution for each of the six loading conditions investigated. Two different time estimates are shown in Table 25. The first is for a complete BWE in which all the ballast tanks that were filled in the given loading condition were cycled. The second is for a limited BWE that excludes those tanks maintained full for all levels of consumables for the operating condition investigated.

Table 19 BWE Analysis Results for the 2824 TEU Ship - Full Load Cargo 10% Consumables										
Tank or Tank Pair	**% Full**	**GM Margin**		**Max BM**	**Max SF**	**Prop Imm.**	**Trim**			**Notes**
		Ft	m	(% Allow)		(%)	Ft	m	[%L]	
Fore Peak (Centerline)	50%	0.49	0.15	69	54	150	6.90	2.10	0.85	
	0%	0.43	0.13	65	52	152	8.22	2.51	1.01	
No 1 Deep Tank (Centerline)	0%	0.34	0.10	63	51	153	8.95	2.73	1.10	
No 1 DBT (Centerline)	50%	0.13	0.04	71	55	149	6.41	1.95	0.79	
	0%	0.19	0.06	70	54	150	7.23	2.20	0.89	
No 2 DBT (P/S)	50%	0.34	0.10	73	56	148	5.96	1.82	0.74	
	0%	0.24	0.07	73	56	148	6.33	1.93	0.78	
No 2 DBT (Centerline)	50%	0.08	0.02	73	56	148	6.21	1.89	0.77	
	0%	0.08	0.02	73	55	149	6.83	2.08	0.84	
No 3A DBT (P/S)	50%	0.31	0.09	73	56	148	5.81	1.77	0.72	
	0%	0.22	0.07	74	56	148	6.03	1.84	0.74	
No 3B DBT (P/S)	50%	0.24	0.07	74	56	148	5.75	1.75	0.71	
	0%	0.14	0.04	76	57	147	5.90	1.80	0.73	
No 3C DBT (P/S)	50%	0.20	0.06	75	57	147	5.63	1.72	0.70	
	0%	0.10	0.03	77	57	147	5.66	1.73	0.70	
No 4 DBT (P/S)	50%	0.08	0.02	75	58	147	5.40	1.65	0.67	
	0%	-0.12	-0.04	77	59	146	5.19	1.58	0.64	1
No 4 DBT (Centerline)	50%	0.00	0.00	75	58	147	5.39	1.64	0.67	
	0%	-0.07	-0.02	77	59	146	5.19	1.58	0.64	2
No 6A Deep Tank (P/S)	50%	0.36	0.11	72	54	146	5.12	1.56	0.63	
	0%	0.18	0.05	71	52	145	4.64	1.41	0.57	
No 6B Deep Tank (P/S)	50%	0.39	0.12	72	55	147	5.22	1.59	0.64	
	0%	0.34	0.10	71	54	146	4.84	1.48	0.60	

Notes: 1) When this tank is cycled @ 10% consumables, the ship has insufficient GM. Calculations indicate that sufficient GM will be available if this tank is cycled earlier in a voyage when the ship has 13% consumables onboard (No 3B HFO Wing tanks (P/S) @ 33% capacity).

2) When this tank is cycled @ 10% consumables, the ship has insufficient GM. Calculations indicate that sufficient GM will be available if this tank is cycled earlier in a voyage when the ship has 12% consumables onboard (No 3B HFO Wing tanks (P/S) @ 24% capacity).

Table 20 BWE Analysis Results for the 2824 TEU Ship - Full Load Cargo 50% Consumables										
Tank or Tank Pair	**% Full**	**GM Margin**		**Max BM**	**Max SF**	**Prop Imm.**	**Trim**			**Notes**
		Ft	m	(% Allow)		(%)	Ft	m	[%L]	
Fore Peak (Centerline)	50%	0.62	0.19	62	46	144	2.09	0.64		
	0%	0.55	0.17	58	44	146	3.33	1.01	0.41	
No 1 Deep Tank (Centerline)	0%	0.46	0.14	57	43	147	4.02	1.23	0.50	
No 1 DBT (Centerline)	50%	0.28	0.09	65	47	143	1.61	0.49	0.20	
	0%	0.32	0.10	63	46	144	2.38	0.73	0.29	
No 2 DBT (P/S)	50%	0.48	0.15	66	48	143	1.19	0.36	0.04	
	0%	0.37	0.11	66	48	143	1.53	0.47	0.18	
No 2 DBT (Centerline)	50%	0.22	0.07	66	48	143	1.42	0.43	0.05	
	0%	0.22	0.07	66	47	144	1.99	0.61	0.25	
No 3A DBT (P/S)	50%	0.46	0.14	67	48	143	1.04	0.32	0.13	
	0%	0.37	0.11	67	48	143	1.24	0.38	0.15	
No 3B DBT (P/S)	50%	0.38	0.12	67	48	142	0.98	0.30	0.12	
	0%	0.28	0.09	69	49	142	1.10	0.34	0.14	
No 3C DBT (P/S)	50%	0.34	0.10	68	49	142	0.86	0.26	0.11	
	0%	0.24	0.07	70	49	142	0.88	0.27	0.11	
No 4 DBT (P/S)	50%	0.44	0.13	67	49	142	0.74	0.23	0.09	
	0%	0.34	0.10	68	49	141	0.63	0.19	0.08	
No 4 DBT (Centerline)	50%	0.15	0.05	68	49	142	0.63	0.19	0.08	
	0%	0.08	0.02	70	51	140	0.41	0.12	0.05	

Table 21 BWE Analysis Results for the 2824 TEU Ship - Full Load Cargo 98% Consumables										
Tank or Tank Pair	**% Full**	**GM Margin**		**Max BM**	**Max SF**	**Prop Imm.**	**Trim**			**Notes**
		Ft	**M**	**(% Allow)**		**(%)**	**Ft**	**M**	**[%L]**	
Fore Peak (Centerline)	0%	0.66	0.20	57	42	146	0.56	0.17	0.07	
No 2 DBT (P/S)	50%	0.57	0.21	61	44	144	-0.31	-0.09	-0.04	1
	0%	0.47	0.14	61	44	144	0.01	0.00	0.00	
No 2 DBT (Centerline)	50%	0.33	0.10	61	44	144	-0.09	-0.03	-0.01	1
	0%	0.32	0.10	61	44	145	0.46	0.14	0.06	
No 3A DBT (P/S)	50%	0.55	0.17	62	45	144	-0.45	-0.14	-0.06	1
	0%	0.46	0.14	62	45	144	-0.26	-0.08	-0.03	1
No 3B DBT (P/S)	50%	0.48	0.15	63	45	144	-0.51	-0.16	-0.06	1
	0%	0.38	0.12	64	45	144	-0.39	-0.11	-0.05	1
No 3C DBT (P/S)	50%	0.44	0.13	63	45	143	-0.62	-0.19	-0.08	1
	0%	0.35	0.11	65	46	143	-0.61	-0.19	-0.08	1
No 4 DBT (P/S)	50%	0.53	0.16	62	45	143	-0.74	-0.23	-0.09	2
	0%	0.44	0.13	64	46	143	-0.85	-0.26	-0.10	2
No 4 DBT (Centerline)	50%	0.26	0.07	63	46	143	-0.85	-0.26	-0.10	2
	0%	0.19	0.06	65	47	142	-1.06	0.32	-0.13	2

Notes: 1) In this operating condition, the ship initially has a –0.63 ft (-0.19 m) trim by the bow. The amount of trim by the bow experienced by the ship when cycling this tank is less than this initial amount of bow trim and thus should pose no operational difficulties.

2) In this operating condition, the ship initially has a –0.63 ft (-0.19 m) trim by the bow. When cycling this tank the ship will take on an additional small amount of bow trim. The magnitude of this trim by the bow is not expected to adversely affect normal ship operations.

Table 22 BWE Analysis Results for the 2824 TEU Ship - Light Load Cargo 10% Consumables										
Tank or Tank Pair	**% Full**	**GM Margin**		**Max BM**	**Max SF**	**Prop Imm.**	**Trim**			**Notes**
		Ft	m	(% Allow)		(%)	Ft	m	[%L]	
Fore Peak (Centerline)	50%	9.40	2.87	95	75	108	1.60	0.49	0.20	
	0%	9.38	2.86	91	72	111	3.25	0.99	0.40	
No 1 Deep Tank (Centerline)	50%	9.67	2.95	90	68	112	4.10	1.25	0.51	
	0%	9.68	2.95	81	58	119	8.31	2.53	1.03	
No 2 Deep Lower Tanks (P/S)	50%	9.31	2.84	94	70	110	2.61	0.80	0.32	
	0%	9.20	2.80	89	62	114	5.28	1.61	0.65	
No 1 DBT (Centerline)	50%	8.92	2.72	97	80	107	0.93	0.28	0.11	
	0%	9.07	2.76	96	81	108	1.90	0.58	0.23	
No 2 DBT (P/S)	50%	9.17	2.80	99	79	106	0.37	0.11	0.05	
	0%	9.10	2.77	99	80	106	0.77	0.23	0.10	
No 2 DBT (Centerline)	50%	8.85	2.70	99	79	106	0.64	0.20	0.08	
	0%	8.96	2.73	99	80	107	1.32	0.40	0.16	
No 3A DBT (P/S)	50%	9.14	2.79	99	79	105	0.17	0.05	0.02	
	0%	9.08	2.77	101	79	105	0.38	0.12	0.05	1
No 3B DBT (P/S)	50%	9.05	2.76	100	79	105	0.06	0.02	0.01	
	0%	8.99	2.74	102	79	105	0.15	0.05	0.02	2
No 3C DBT (P/S)	50%	9.00	2.74	100	79	105	-0.10	-0.03	-0.01	3
	0%	8.95	2.73	102	79	104	-0.17	-0.05	-0.02	3&4
No 4 DBT (P/S)	50%	8.87	2.70	100	78	102	-0.46	-0.14	-0.06	3
	0%	8.72	2.66	101	78	104	-0.90	-0.27	-0.11	3&5
No 4 DBT (Centerline)	0%	9.34	2.85	99	78	102	-0.45	-0.14	-0.05	3
No 4 Wing Tanks (P/S)	50%	9.20	2.80	101	78	102	-1.02	-0.31	-0.13	3&6
	0%	8.61	2.62	104	78	97	-2.28	-0.69	-0.28	3&6

Notes: 1) When this tank is cycled @ 10% consumables, the ship experiences excessive Bending Moment. Calculations indicate that Bending Moment can be reduced sufficiently if this tank is cycled earlier in a voyage when the ship has 13% consumables onboard (No 3B HFO Wing tanks @ 15% capacity).

2) When this tank is cycled @ 10% consumables, the ship experiences excessive Bending Moment. Calculations indicate that Bending Moment can be reduced sufficiently if this tank is cycled earlier in a voyage when the ship has 14% consumables onboard (No 3B HFO Wing tanks @ 26% capacity).

3) In this operating condition, the ship initially has a –0.03 ft (-0.01 m) trim by the bow. When cycling this tank the ship will take on an additional small amount of bow trim. The magnitude of this trim by the bow is not expected to adversely affect normal ship operations.

4) When this tank is cycled @ 10% consumables, the ship experiences excessive Bending Moment. Calculations indicate that Bending Moment can be reduced sufficiently if this tank is cycled earlier in a voyage when the ship has 15% consumables onboard (No 3B HFO Wing tanks @ 28% capacity).

5) When this tank is cycled @ 10% consumables, the ship experiences excessive Bending Moment. Calculations indicate that Bending Moment can be reduced sufficiently if this tank is cycled earlier in a voyage when the ship has 12.5% consumables onboard (No 3B HFO Wing tanks @ 13% capacity).

6) When this tank is cycled @ 10% consumables, the ship experiences excessive Bending Moment and propeller tip emergence. Calculations indicate that Bending Moment can be reduced sufficiently, and propeller tip emergence avoided, if this tank is cycled earlier in a voyage when the ship has 21% consumables onboard (No 3B HFO Wing tanks @ 72% capacity).

Table 23 BWE Analysis Results for the 2824 TEU Ship - Light Load Cargo 50% Consumables										
Tank or Tank Pair	**% Full**	**GM Margin**		**Max BM**	**Max SF**	**Prop Imm.**	**Trim**			**Notes**
		Ft	m	(% Allow)		(%)	Ft	m	[%L]	
Fore Peak (Centerline)	50%	8.97	2.73	87	54	109	1.86	0.57	0.23	
	0%	8.95	2.73	84	53	112	3.51	1.07	0.43	
No 1 Deep Tank (Centerline)	50%	9.23	2.81	83	52	113	4.36	1.33	0.54	
	0%	9.23	2.81	75	49	120	8.57	2.61	1.06	
No 1 DBT (Centerline)	50%	8.48	2.58	89	59	107	1.19	0.36	0.15	
	0%	8.63	2.63	88	60	109	2.16	0.66	0.27	
No 2 DBT (P/S)	50%	8.74	2.66	90	58	107	0.63	0.19	0.08	
	0%	8.66	2.64	90	59	107	1.03	0.31	0.13	
No 2 DBT (Centerline)	50%	8.42	2.57	90	59	107	0.91	0.28	0.11	
	0%	8.52	2.60	90	60	107	1.59	0.48	0.20	
No 3A DBT (P/S)	50%	8.71	2.65	91	58	106	0.44	0.13	0.05	
	0%	8.64	2.63	91	59	106	0.64	0.20	0.08	
No 3B DBT (P/S)	50%	8.62	2.63	91	58	106	0.32	0.10	0.04	
	0%	8.55	2.61	92	58	105	0.42	0.13	0.05	
No 3C DBT (P/S)	50%	8.57	2.61	92	58	105	0.16	0.05	0.02	
	0%	8.51	2.59	94	58	105	0.09	0.03	0.01	
No 4 DBT (P/S)	50%	8.44	2.57	92	58	105	-0.20	-0.06	-0.02	1
	0%	8.28	2.52	94	58	103	-0.64	-0.20	-0.08	1
No 4 Wing Tanks (P/S)	0%	8.78	2.68	91	58	105	-0.01	-0.00	-0.00	1

Notes: 1) When cycling this tank the ship takes on a small amount of trim by the bow. The magnitude of this trim by the bow is not expected to adversely affect normal ship operations.

Table 24 BWE Analysis Results for the 2824 TEU Ship - Light Load Cargo 98% Consumables										
Tank or Tank Pair	**% Full**	**GM Margin**		**Max BM**	**Max SF**	**Prop Imm.**	**Trim**			**Notes**
		Ft	m	(% Allow)		(%)	Ft	m	[%L]	
Fore Peak (Centerline)	50%	8.95	2.73	80	52	113	1.70	0.52	0.21	
	0%	8.95	2.73	77	49	116	3.31	1.01	0.41	
No 1 DBT (Centerline)	50%	8.49	2.59	82	56	112	1.05	0.32	0.13	
	0%	8.64	2.63	81	57	113	2.00	0.61	0.25	
No 2 DBT (P/S)	50%	8.73	2.66	83	55	111	0.51	0.16	0.06	
	0%	8.66	2.64	84	56	111	0.90	0.61	0.25	
No 2 DBT (Centerline)	50%	8.43	2.57	83	56	111	0.78	0.24	0.10	
	0%	8.53	2.60	83	57	112	1.45	0.44	0.18	
No 3A DBT (P/S)	50%	8.69	2.65	84	55	111	0.32	0.10	0.04	
	0%	8.64	2.63	85	56	111	0.52	0.16	0.06	
No 3B DBT (P/S)	50%	8.61	2.62	85	55	110	0.21	0.06	0.03	
	0%	8.56	2.61	86	56	110	0.31	0.09	0.04	
No 3C DBT (P/S)	50%	8.56	2.61	85	55	110	0.06	0.02	0.01	
	0%	8.51	2.59	87	55	109	0.00	0.00	0.00	
No 4 DBT (P/S)	50%	8.44	2.57	85	55	109	-0.29	-0.09	-0.04	1
	0%	8.29	2.53	87	55	107	-0.71	-0.22	-0.09	1
No 4 Wing Tanks (P/S)	0%	8.76	2.67	84	55	110	-0.12	-0.04	-0.01	1

Notes: 1) When cycling this tank the ship takes on a small amount of trim by the bow. The magnitude of this trim by the bow is not expected to adversely affect normal ship operations.

Table 25 Estimated Time Requirements for BWE for the 2824 TEU SHIP		
Operating Condition	**Time (hrs)**	
	Complete BWE	Limited BWE
Full Load 10% Consumables	19.6	10.0
Full Load 50% Consumables	16.5	6.9
Full Load 98% Consumables	11.5	1.9
Light Load 10% Consumables	28.2	15.0
Light Load 50% Consumables	18.6	5.4
Light Load 98% Consumables	13.8	0.6

3918 TEU Ship

The results of the BWE analysis for the 3918 TEU ship are shown in Tables 26 through 32. These tables show the impact on the ship's available GM, maximum bending moment, maximum shear stress, propeller immersion, and trim experienced by the ship as each ballast tank or tank pair is cycled during the BWE evolution for each loading condition investigated. Available GM is shown as the Margin in GM that the ship has above its minimum requirements at the ship's current draft and trim. Conditions where this margin is less than 0.5ft (0.15m) have been shaded for easy identification. The maximum bending moment and shear forces experienced when cycling each tank or tank pair is shown as a percent of the maximum allowable bending moments and shear forces for the vessel. Conditions where the maximum bending moment and shear forces exceed 95% of the allowable bending moment or shear forces have been shaded for easy identification. Propeller immersion is measured as the draft at the propeller as a percent of the propeller diameter. Conditions where the propeller immersion is less than 105% of the propeller diameter have been shaded for easy identification. Table 32 shows the estimated time required to complete a BWE evolution for each of the six loading conditions investigated. Two different time estimates are shown in Table 32. The first is for a complete BWE in which all the ballast tanks that were filled in the given loading condition were cycled. The second is for a limited BWE that excludes those tanks maintained full for all levels of consumables for the operating condition investigated.

Table 26 BWE Analysis Results for 3918 TEU Ship - Full Load Cargo 10% Consumables										
Tank or Tank Pair	**% Full**	**GM Margin**		**Max BM**	**Max SF**	**Prop Imm.**	**Trim**			**Notes**
		Ft	m	(% Allow)		(%)	Ft	m	[%L]	
No 1 Deep Tank (Centerline)	50%	0.62	0.19	54	30	162	5.87	1.79	0.72	
	0%	0.47	0.14	50	26	166	8.07	2.46	0.99	
No 1 DBT (P/S)	50%	0.62	0.19	56	32	161	5.05	1.54	0.62	
	0%	0.43	0.13	53	34	163	6.40	1.95	0.79	
No 2 DBT (P/S)	50%	0.45	0.14	58	42	160	4.42	1.35	0.54	
	0%	0.45	0.14	57	46	161	5.21	1.59	0.64	
No 3 DBT (P/S)	50%	0.53	0.16	58	41	159	4.05	1.23	0.50	
	0%	0.59	0.18	59	43	160	4.43	1.35	0.54	
No 4 DBT (P/S)	50%	-0.03	-0.01	60	42	159	4.07	1.24	0.50	1
	0%	0.16	0.05	62	46	158	4.44	1.35	0.54	
No 7 DBT (P/S)	50%	0.00	0.00	62	40	158	3.50	1.07	0.43	
	0%	0.16	0.05	66	42	156	3.31	1.01	0.41	
No 8 DBT (P/S)	50%	0.11	0.03	61	39	157	3.02	0.92	0.37	
	0%	0.23	0.07	64	39	154	2.33	0.71	0.29	
No 9 DBT (P/S)	50%	0.58	0.18	58	38	157	3.00	0.91	0.37	
	0%	0.52	0.16	58	37	155	2.30	0.70	0.28	
No 2 Wing Ballast Tank (P/S)	50%	0.72	0.22	57	47	161	5.35	1.63	0.66	
	0%	0.34	0.11	56	55	163	7.04	2.15	0.86	
No 7 Wing Ballast Tank (P/S)	50%	0.82	0.25	63	41	157	3.46	1.05	0.42	
	0%	0.47	0.14	68	43	155	3.22	0.98	0.40	
No 8 Wing Ballast Tank (P/S)	50%	0.82	0.25	62	39	156	2.83	0.86	0.35	
	0%	0.50	0.15	66	39	153	1.94	0.59	0.24	

Notes: 1) When this tank is cycled @ 10% consumables, the ship has insufficient GM. Calculations indicate that sufficient GM will be available if this tank is cycled earlier in a voyage when the ship has 15% consumables onboard (No 3 HFO Wing tanks @ 98% capacity).

Table 27 BWE Analysis Results for 3918 TEU Ship - Full Load Cargo 98% Consumables										
Tank or Tank Pair	**% Full**	**GM Margin**		**Max BM**	**Max SF**	**Prop Imm.**	**Trim**			**Notes**
		Ft	m	(% Allow)		(%)	Ft	m	[%L]	
No 1 Deep Tank (Centerline)	50%	1.74	0.53	78	63	164	2.72	0.83	0.33	
	0%	1.56	0.48	73	55	167	4.81	1.47	0.59	
No 1 DBT (P/S)	50%	1.74	0.53	80	64	163	1.97	0.60	0.24	
	0%	1.56	0.48	77	57	165	3.25	0.99	0.40	
No 2 DBT (P/S)	50%	1.56	0.48	82	75	162	1.41	0.43	0.17	
	0%	1.56	0.48	81	79	163	2.13	0.65	0.26	
No 3 DBT (P/S)	50%	1.65	0.50	82	74	162	1.05	0.32	0.13	
	0%	1.71	0.52	83	76	162	1.38	0.42	0.17	
No 4 DBT (P/S)	50%	1.11	0.34	84	75	161	1.05	0.32	0.13	
	0%	1.28	0.39	86	79	160	1.41	0.43	0.17	
No 7 DBT (P/S)	50%	1.14	0.35	86	73	160	0.52	0.16	0.06	
	0%	1.28	0.39	90	75	158	0.33	0.10	0.04	
No 8 DBT (P/S)	50%	1.24	0.38	85	72	159	0.07	0.02	0.01	
	0%	1.35	0.41	88	72	156	0.57	0.17	0.07	
No 9 DBT (P/S)	50%	1.71	0.52	82	71	159	0.07	0.02	0.01	
	0%	1.64	0.50	82	70	157	-0.60	-0.18	-0.07	1
No 2 Wing Ballast Tank (P/S)	50%	1.80	0.55	81	80	163	2.26	0.69	0.28	
	0%	1.43	0.44	80	88	164	3.84	1.17	0.47	
No 7 Wing Ballast Tank (P/S)	0%	1.74	0.53	87	74	159	0.49	0.15	0.06	

Notes: 1) When cycling this tank the ship takes on a small amount of trim by the bow. The magnitude of this trim by the bow is not expected to adversely affect normal ship operations.

Table 28 BWE Analysis Results for 3918 TEU Ship - Design Load Cargo 10% Consumables										
Tank or Tank Pair	**% Full**	**GM Margin**		**Max BM**	**Max SF**	**Prop Imm.**	**Trim**			**Notes**
		Ft	m	(% Allow)		(%)	Ft	m	[%L]	
Fore Peak Tank	0%	0.93	0.28	73	60	138	5.39	1.64	0.66	
No 1 Deep Tank	50%	0.92	0.28	76	61	136	4.13	1.26	0.51	
	0%	0.79	0.24	72	53	140	6.56	2.00	0.81	
No 1 DBT (P/S)	50%	0.85	0.26	78	62	134	3.22	0.98	0.40	
	0%	0.70	0.21	76	58	137	4.70	1.43	0.58	
No 2 DBT (P/S)	50%	0.66	0.20	79	73	133	2.53	0.77	0.31	
	0%	0.72	0.22	79	77	134	3.34	1.02	0.41	
No 3 DBT (P/S)	50%	0.74	0.23	80	71	132	2.10	0.64	0.26	
	0%	0.85	0.26	80	74	133	2.47	0.75	0.30	
No 4 DBT (P/S)	50%	0.12	0.04	82	73	132	2.03	0.62	0.25	
	0%	0.43	0.13	84	76	131	2.38	0.72	0.29	
No 7 DBT (P/S)	50%	0.15	0.05	83	71	130	1.40	0.43	0.17	
	0%	0.43	0.13	87	72	128	1.08	0.33	0.13	
No 8 DBT (P/S)	50%	0.27	0.08	82	69	129	0.85	0.26	0.10	
	0%	0.52	0.16	84	69	126	-0.03	-0.01	-0.00	1
No 9 DBT (P/S)	50%	0.82	0.25	79	68	130	0.87	0.27	0.11	
	0%	0.79	0.24	78	67	127	0.00	0.00	0.00	
No 2 Wing Ballast Tank (P/S)	50%	1.05	0.32	79	78	134	3.48	1.06	0.43	
	0%	0.71	0.22	78	86	136	5.28	1.61	0.65	
No 7 Wing Ballast Tank (P/S)	50%	1.15	0.35	84	71	130	1.33	0.41	0.16	
	0%	0.83	0.25	89	73	127	0.92	0.28	0.11	
No 4 Upper Tank (P/S)	50%	1.28	0.39	80	70	132	1.84	0.56	0.23	
	0%	1.38	0.42	82	73	131	2.11	0.64	0.26	

Notes: 1) When cycling this tank the ship takes on a small amount of trim by the bow. The magnitude of this trim by the bow is not expected to adversely affect normal ship operations.

Table 29 BWE Analysis Results for 3918 TEU Ship - Design Load Cargo 98% Consumables

Tank or Tank Pair	% Full	GM Margin		Max BM	Max SF	Prop Imm.	Trim			Notes
		Ft	m	(% Allow)		(%)	Ft	m	[%L]	
No 1 Deep Tank (Centerline)	50%	1.08	0.33	92	85	144	4.59	1.40	0.56	
	0%	0.95	0.29	88	77	148	6.99	2.13	0.86	
No 1 DBT (P/S)	50%	1.02	0.31	94	87	143	3.71	1.13	0.46	
	0%	0.85	0.26	92	80	145	5.15	1.57	0.63	
No 2 DBT (P/S)	50%	0.85	0.26	96	98	141	3.05	0.93	0.37	
	0%	0.89	0.27	95	101	142	3.84	1.17	0.47	1
No 3 DBT (P/S)	50%	0.92	0.28	96	96	141	2.62	0.80	0.32	
	0%	1.02	0.31	97	98	141	2.99	0.91	0.37	
No 4 DBT (P/S)	50%	0.33	0.10	98	97	140	2.59	0.79	0.32	
	0%	0.59	0.18	100	101	139	2.95	0.90	0.36	2
No 7 DBT (P/S)	50%	0.36	0.11	100	95	139	1.97	0.60	0.24	
	0%	0.62	0.19	104	97	137	1.67	0.51	0.21	3
No 8 DBT (P/S)	50%	0.46	0.14	99	94	138	1.44	0.44	0.18	
	0%	0.69	0.21	101	94	135	0.62	0.19	0.08	4
No 2 Wing Ballast Tank (P/S)	50%	1.18	0.36	95	102	142	4.00	1.22	0.49	5
	0%	0.85	0.26	94	110	144	5.74	1.75	0.70	5
No 3 Upper Tank (P/S)	50%	1.44	0.44	96	95	141	2.53	0.77	0.31	
	0%	1.44	0.44	96	97	141	2.76	0.84	0.34	
No 4 Upper Tank (P/S)	0%	1.41	0.43	97	95	140	2.43	0.74	0.30	

Notes: 1) When this tank is cycled @ 98% consumables, the ship experiences excessive Shear Force. Calculations indicate that the Shear Force can be reduced sufficiently if this tank is cycled later in a voyage when the ship has 96% consumables onboard (No 1 HFO tanks @ 93% capacity).

2) When this tank is cycled @ 98% consumables, the ship experiences excessive Shear Force. Calculations indicate that the Shear Force can be reduced sufficiently if this tank is cycled later in a voyage when the ship has 97% consumables onboard (No 1 HFO tanks @ 95% capacity).

3) When this tank is cycled @ 98% consumables, the ship experiences excessive Bending Moment. Calculations indicate that Bending Moment can be reduced sufficiently if this tank is cycled later in a voyage when the ship has 80% consumables onboard (No 1 HFO tanks @ 55% capacity).

4) When this tank is cycled @ 98% consumables, the ship experiences excessive Bending Moment. Calculations indicate that Bending Moment can be reduced sufficiently if this tank is cycled later in a voyage when the ship has 92% consumables onboard (No 1 HFO tanks @ 84% capacity).

5) When this tank is cycled @ 98% consumables, the ship experiences excessive Shear Force. Calculations indicate that the Shear Force can be reduced sufficiently if this tank is cycled later in a voyage when the ship has 85% consumables onboard (No 1 HFO tanks @ 66% capacity).

Table 30 BWE Analysis Results for 3918 TEU Ship - Ballast Condition 10% Consumables

Tank or Tank Pair	**% Full**	**GM Margin**		**Max BM**	**Max SF**	**Prop Imm.**	**Trim**			**Notes**
		Ft	m	(% Allow)		(%)	Ft	m	[%L]	
No 1 Deep Tank (Centerline)	50%	12.66	3.86	57	49	116	12.43	3.79	1.53	1
	0%	12.66	3.86	54	40	121	15.03	4.58	1.84	1
No 1 DBT (P/S)	50%	12.57	3.83	59	50	114	11.42	3.48	1.40	
	0%	12.43	3.79	57	49	117	13.00	3.97	1.60	1
No 2 DBT (P/S)	50%	12.24	3.73	60	61	113	10.70	3.26	1.31	
	0%	12.43	3.79	60	65	114	11.55	3.52	1.42	
No 3 DBT (P/S)	50%	12.34	3.76	61	59	112	10.20	3.11	1.25	
	0%	12.57	3.83	61	61	112	10.60	3.23	1.30	
No 4 DBT (P/S)	50%	11.52	3.51	62	60	111	10.14	3.09	1.24	
	0%	12.14	3.70	64	63	110	10.43	3.18	1.28	
No 7 DBT (P/S)	50%	11.55	3.52	64	58	110	9.42	2.87	1.16	
	0%	12.14	3.70	67	60	107	8.99	2.74	1.10	

No 8 DBT (P/S)	50%	11.71	3.57	62	57	108	8.83	2.69	1.08	
	0%	12.20	3.72	64	56	105	7.81	2.38	0.96	
No 9 DBT (P/S)	50%	12.43	3.79	60	56	109	8.86	2.70	1.09	
	0%	12.50	3.81	59	55	106	7.87	2.40	0.97	
No 2 Wing Ballast Tank (P/S)	50%	12.93	3.94	60	65	114	11.71	3.57	1.44	
	0%	12.63	3.85	59	73	116	13.58	4.14	1.67	1
No 7 Wing Ballast Tank (P/S)	50%	13.02	3.97	65	59	109	9.32	2.84	1.14	
	0%	12.76	3.89	69	60	106	8.83	2.69	1.08	
No 8 Wing Ballast Tank (P/S)	50%	13.02	3.97	63	56	107	8.53	2.60	1.05	
	0%	12.80	3.90	65	56	103	7.22	2.20	0.89	
No 3 Upper Tank (P/S)	50%	13.09	3.99	61	58	112	10.10	3.08	1.24	
	0%	13.19	4.02	61	60	112	10.37	3.16	1.27	
No 4 Upper Tank (P/S)	50%	13.22	4.03	62	59	111	10.04	3.06	1.23	
	0%	13.42	4.09	63	61	111	10.20	3.11	1.25	
No 7 Upper Tank (P/S)	50%	13.22	4.03	63	58	110	9.58	2.92	1.18	
	0%	13.42	4.09	65	59	109	9.32	2.84	1.14	
No 8 Upper Tank (P/S)	50%	13.22	4.03	62	57	109	9.12	2.78	1.12	
	0%	13.42	4.09	63	56	107	8.40	2.56	1.03	

Notes: 1) When cycling this tank the ship will trim by the stern by more than 1.5% of the ship's length. This much trim could potentially cause some operational difficulties for the ship.

Table 31 BWE Analysis Results for 3918 TEU Ship - Ballast Condition 98% Consumables										
Tank or Tank Pair	**% Full**	**GM Margin**		**Max BM**	**Max SF**	**Prop Imm.**	**Trim**			**Notes**
		Ft	m	(% Allow)		(%)	Ft	m	[%L]	
No 1 Deep Tank (Centerline)	50%	12.63	3.85	73	83	131	12.57	3.83	1.54	1
	0%	12.66	3.86	69	75	135	15.09	4.60	1.85	1
No 1 DBT (P/S)	50%	12.53	3.82	75	84	129	11.58	3.53	1.42	
	0%	12.43	3.79	73	77	131	13.16	4.01	1.62	1
No 2 DBT (P/S)	50%	12.24	3.73	76	95	128	10.86	3.31	1.33	
	0%	12.43	3.79	76	99	129	11.71	3.57	1.44	
No 3 DBT (P/S)	50%	12.30	3.75	77	93	127	10.40	3.17	1.28	
	0%	12.53	3.82	77	96	127	10.79	3.29	0.40	
No 4 DBT (P/S)	50%	11.65	3.55	78	95	126	10.33	3.15	1.27	
	0%	12.20	3.72	80	98	125	10.66	3.25	1.31	
No 7 DBT (P/S)	50%	11.68	3.56	80	93	125	9.65	2.94	1.18	
	0%	11.68	3.56	83	94	122	9.25	2.82	1.14	
No 8 DBT (P/S)	50%	11.81	3.60	79	91	123	9.09	2.77	1.12	
	0%	12.27	3.74	81	91	120	8.10	2.47	0.99	
No 9 DBT (P/S)	50%	12.40	3.78	76	90	124	9.09	2.77	1.12	
	0%	12.50	3.81	75	89	121	8.17	2.49	1.00	
No 2 Wing Ballast Tank (P/S)	50%	12.86	3.92	76	100	129	11.88	3.62	1.46	
	0%	12.66	3.86	75	108	131	13.71	4.18	1.68	1&2
No 7 Wing Ballast Tank (P/S)	50%	12.93	3.94	81	93	124	9.58	2.92	1.18	
	0%	12.76	3.89	85	95	121	9.09	2.77	1.12	
No 8 Wing Ballast Tank (P/S)	50%	12.93	3.94	79	91	122	8.79	2.68	1.08	
	0%	12.80	3.90	82	91	118	7.55	2.30	0.93	
No 3 Upper Tank (P/S)	50%	12.96	3.95	77	93	127	10.30	3.14	1.26	
	0%	13.06	3.98	77	94	127	10.56	3.22	1.30	
No 4 Upper Tank (P/S)	50%	13.09	3.99	78	93	126	10.24	3.12	1.26	

	0%	13.29	4.05	79	96	126	10.43	3.18	1.28	
No 7 Upper Tank (P/S)	50%	13.09	3.99	79	92	125	9.78	2.98	1.20	
	0%	13.25	4.04	81	93	124	9.55	2.91	1.17	
No 8 Upper Tank (P/S)	50%	13.09	3.99	78	91	124	9.35	2.85	1.15	
	0%	13.25	4.04	79	91	122	8.66	2.64	1.06	

Notes: 1) When cycling this tank the ship will trim by the stern by more than 1.5% of the ship's length. This much trim could potentially cause some operational difficulties for the ship.

2) When this tank is cycled @ 98% consumables, the ship experiences excessive Shear Force. Calculations indicate that the Shear Force can be reduced sufficiently if this tank is cycled later in a voyage when the ship has 90% consumables onboard (No 1 HFO tanks @ 75% capacity).

Table 32 Estimated Time Requirements for BWE for the 3918 TEU Ship

Operating Condition	**Time (hrs)**	
	Complete BWE	Limited BWE
Full Load 10% Consumables	45.3	13.1
Full Load 98% Consumables	37.3	5.1
Design Load 10% Consumables	45.7	10.6
Design Load 98% Consumables	34.8	2.6
Ballast Cond. 10% Consumables	55.3	23.2
Ballast Cond. 98% Consumables	55.3	23.2

Tables 26 through 31 show that the actual cargo arrangement and fuel/stores load out impacts the magnitude of the bending moment and shear stress experienced by the ship during the BWE. For this ship bending moment and shear force limitations place a greater constraint on conducting a BWE at sea in the Design (or intermediate cargo loadout) condition than in either the Full Load or Ballast conditions. This leads to the conclusion that a ship could experience a higher bending moment or shear stress when loaded with less than a full load of cargo and/or fuel/stores than when the ship was fully loaded with cargo and fuel/stores.

REANALYSIS OF THE 3918 TEU SHIP

Two load cases for the 3918 TEU ship were reanalyzed. In the initial analysis, the Design Load with 98% consumables was identified as the condition most limited by bending moment and shear forces. As such it was reanalyzed to assess the impact that diagonally pairing port and starboard ballast tanks would have on the bending moments and shear forces experienced during a BWE evolution.

The Full Load with 10% consumables onboard condition was identified as the most stability limited of the loading conditions in the initial analysis. As such, this load condition was reanalyzed to assess the ship's stability characteristics when each tank or tank pair was deballasted to 10% capacity during the BWE.

Table 33 shows the results of the reanalysis of the Design Load 98% consumables condition for the 3918 TEU ship. In this reanalysis alternate diagonal tank pairings were investigated to see if they would alleviate the excess bending moments or shear stresses encountered in the original analysis. Excess shear forces were encountered when cycling No2 DBT P/S, No4 DBT P/S, and No2 Wing Ballast Tank P/S. Excess Bending Moments were encountered when cycling No 7 DBT P/S and No 8 DBT P/S.

Table 33 BWE Reanalysis for 3918 TEU Ship - Design Load Cargo 98% Consumables

Tank or Tank Pair	**% Full**	**GM Margin**		**Max BM**	**Max SF**	**Prop Imm.**	**Trim**			**Notes**
		Ft	m	(% Allow)		(%)	Ft	m	[%L]	
No1 DBT/ No2 DBT Diag Pair	50%	0.94	0.29	95	92	142	3.38	1.03	0.41	
	0%	0.87	0.27	94	91	143	4.51	1.37	0.55	
No2 DBT/ No3 DBT Diag Pair	50%	0.88	0.67	96	97	141	2.84	0.87	0.35	
	0%	0.95	0.29	96	100	142	3.43	1.04	0.42	
No3 DBT/ No4 DBT Diag Pair	50%	0.62	0.19	97	96	140	2.61	0.80	0.32	
	0%	0.81	0.25	98	99	140	2.97	0.90	0.36	
No4 DBT/ No7 DBT Diag Pair	50%	0.33	0.10	99	96	139	2.28	0.70	0.28	
	0%	0.60	0.18	102	99	138	2.30	0.70	0.28	1
No7 DBT/ No8 DBT Diag Pair	50%	0.41	0.13	99	94	138	1.71	0.52	0.21	
	0%	0.64	0.20	102	95	136	1.14	0.35	0.14	2
No3 UPP/ No2 WB Diag Pair	50%	1.31	0.40	96	99	142	3.25	0.99	0.40	
	0%	1.15	0.35	95	104	143	4.26	1.30	0.52	3

Notes: 1) When this tank is cycled @ 98% consumables, the ship experiences excessive Bending Moment. Calculations indicate that the Bending Moment can be reduced sufficiently if this tank is cycled later in a voyage when the ship has 89% consumables onboard (No 1 HFO tanks @ 75% capacity).

2) When this tank is cycled @ 98% consumables, the ship experiences excessive Bending Moment. Calculations indicate that the Bending Moment can be reduced sufficiently if this tank is cycled later in a voyage when the ship has 87% consumables onboard (No 1 HFO tanks @ 70% capacity).

3) When this tank is cycled @ 98% consumables, the ship experiences excessive Bending Moment. Calculations indicate that Bending Moment can be reduced sufficiently if this tank is cycled later in a voyage when the ship has 94% consumables onboard (No 1 HFO tanks @ 87% capacity).

As can be seen from these results diagonal pairing of port and starboard ballast tanks provides some benefits during a BWE evolution. In particular, the excess shear stresses encountered in cycling No2 DBT P/S could be avoided by diagonally paring tanks from either No1 DBT or No3 DBT with No2 DBT. The excess shear stresses encountered in cycling No4 DBT P/S could be avoided by diagonally paring tanks from No3 DBT with No4 DBT.

The excess bending moments encountered when cycling No7 DBT can be reduced, but not eliminated, by diagonally paring tanks from No7 DBT with either tanks from No4 DBT or No 8 DBT. This excess bending moment could be avoided if these tank pairs are cycled earlier in the BWE evolution.

The excess shear forces encountered during the cycling of No 2 Wing Ballast Tank can be reduced, but not eliminated, by diagonally pairing No3 Upper Tank with No2 Wing Ballast Tank. This excess bending moment could be avoided if these tank pairs are cycled earlier in the BWE evolution. Other tank paring combinationsdid not result in any significant changes.

The results of the reanalysis of the Full Load 10% Consumables condition for the 3918 TEU ship are shown in Table 34. As can be seen from these results there are two tank pairs which cause stability problems which were not identified during the initial analysis. Both these problems can be alleviated if these tanks are cycled earlier in the BWE evolution before the ship reaches a 10% consumables level. The reanalysis indicates that when developing a BWE sequence for a ship, care should be taken to ensure that the ship retains adequate stability over the entire evolution. Also, a ship's stability when a given tank or tank pair is deballasted to ~10% is likely to be more critical than when the tank is deballasted to a 50% capacity level.

Table 34 BWE Reanalysis for 3918 TEU Ship - Full Load Cargo 10% Consumables

Tank or Tank Pair	**% Full**	**GM Margin**		**Max BM**	**Max SF**	**Prop Imm.**	**Trim**			**Notes**
		Ft	m	(% Allow)		(%)	Ft	m	[%L]	
No 1 Deep Tank (Centerline)	10%	0.40	0.12	51	26	165	7.62	2.23	0.93	
	0%	0.47	0.14	50	26	166	8.07	2.46	0.99	
No 1 DBT (P/S)	10%	0.40	0.12	54	34	163	6.13	1.87	0.75	
	0%	0.43	0.13	53	34	163	6.40	1.95	0.79	
No 2 DBT (P/S)	10%	0.24	0.07	57	45	161	5.06	1.54	0.62	
	0%	0.45	0.14	57	46	161	5.21	1.59	0.64	
No 3 DBT (P/S)	10%	0.38	.12	59	42	160	4.34	1.32	0.53	
	0%	0.59	0.18	59	43	160	4.43	1.35	0.54	
No 4 DBT (P/S)	10%	-0.36	-0.11	62	45	158	4.36	1.33	0.54	1
	0%	0.16	0.05	62	46	158	4.44	1.35	0.54	
No 7 DBT (P/S)	10%	-0.32	-.10	65	42	156	3.34	1.02	0.41	2
	0%	0.16	0.05	66	42	156	3.31	1.01	0.41	

No 8 DBT (P/S)	10%	-0.18	-0.06	63	39	155	2.47	0.75	0.30	3
	0%	0.23	0.07	64	39	154	2.33	0.71	0.29	
No 9 DBT (P/S)	10%	0.40	0.12	58	37	155	2.44	0.75	0.30	
	0%	0.52	0.16	58	37	155	2.30	0.70	0.28	
No 2 Wing Ballast Tank (P/S)	10%	0.39	0.12	56	54	162	6.70	2.04	0.82	
	0%	0.34	0.11	56	55	163	7.04	2.15	0.86	
No 7 Wing Ballast Tank (P/S)	10%	0.55	0.17	67	43	156	3.26	1.00	0.40	
	0%	0.47	0.14	68	43	155	3.22	0.98	0.40	
No 8 Wing Ballast Tank (P/S)	10%	0.57	0.18	65	39	153	2.12	0.65	0.26	
	0%	0.50	0.15	66	39	153	1.94	0.59	0.24	

Notes: 1) When this tank is cycled @ 10% consumables, the ship has insufficient GM. Calculations indicate that sufficient GM will be available if this tank is cycled earlier in a voyage when the ship has 28% consumables onboard (No 4 HFO Wing tanks @ 45% capacity).

2) When this tank is cycled @ 10% consumables, the ship has insufficient GM. Calculations indicate that sufficient GM will be available if this tank is cycled earlier in a voyage when the ship has 26% consumables onboard (No 4 HFO Wing tanks @ 40% capacity).

3) When this tank is cycled @ 10% consumables, the ship has insufficient GM. Calculations indicate that sufficient GM will be available if this tank is cycled earlier in a voyage when the ship has 21% consumables onboard (No 4 HFO Wing tanks @ 20% capacity).